

APPLICATION FOR UNITED STATES PATENT

FOR

**INTEGRATION OF MULTIPLE FREQUENCY BAND FBAR
FILTERS**

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TECHNICAL FIELD & BACKGROUND

The present invention is related to the field of Microelectromechanical Systems (MEMS). More specifically, the present invention is related to 5 integration of film bulk acoustic resonators (FBAR) filters for different frequency bands.

Radio frequency (RF) front-end passives, such as transceivers and receivers are increasingly needed for wireless communication. These front-end passives include front-end filters. RF front-end filters consisting of FBAR have 10 been found to have a number of advantages over other technologies, such as surface acoustic wave (SAW) devices and ceramic filters, particularly at relatively high frequencies.

The thickness of the film stack of a FBAR filter is generally governed by the half wavelength of the frequency band of the FBAR filter. For example, the 15 thickness of the film stack of a FBAR filter for the 1900 MHz frequency band is about 1.8 μm , whereas the thickness of the film stack of a FBAR filter for the 950 MHz frequency band is about 3.6 μm .

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in
5 which like references denote similar elements, and in which:

Figure 1 illustrates a simplified cross section view of a component having FBAR filters with film stacks of different thickness for different frequency bands;

Figure 2 illustrates a simplified cross section view of an ionized physical vapor deposition apparatus suitable for use to form the layers of the different
10 frequency band/thickness FBAR filters of **Fig. 1** via the same process operations, in accordance with one embodiment;

Figure 3 illustrates a flow chart depicting the method of the present invention for making different film stack layers of different FBAR filters of different frequency bands via the same process operation, in accordance with one
15 embodiment; and

Figure 4 illustrates a system having a component of **Fig. 1** formed using e.g. the IPVD apparatus of **Fig. 2** and the process of **Fig. 3**, in accordance with one embodiment.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Embodiments of the present invention include, but are not limited to, a component having multiple different frequency band FBAR filters with film stacks of different thickness, where at least some film stack layers of different filters are formed via the same process operation(s), a method for making such component, and a system having such component.

Various aspects of the illustrative embodiments will be described using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some of the described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the illustrative embodiments.

Various operations will be described as multiple discrete operations, in turn, in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

Referring now to **Fig. 1**, wherein a simplified cross section view of a component having FBAR filters of different frequency bands, in accordance with one embodiment, is shown. As illustrated, component **100** includes multiple 5 FBAR filters **102a-102b** for different frequency bands. Accordingly, FBAR filters **102a-102b** have film stacks **104a-104b** of corresponding different thicknesses (t1 and t2).

In various embodiments, each film stack **104a/104b** includes a piezoelectric layer **112**, sandwiched between two metal layers **114a-114b**. The 10 thickness of each of the layers **114a**, **112** and **114b** is proportional to the overall corresponding thickness (t1 and t2).

In various embodiments, the piezoelectric layer **112** may be formed with materials such as Aluminum Nitride (AlN), Lead Zirconate Titanate (PZT), Zinc Oxide (ZnO) and so forth, while each of the metal layers **114** may be formed with 15 materials such as Molybium (Mo), Platinum (Pt), Tungsten (W) and so forth.

As will be described in more detail below, notwithstanding the film stack layers' differences in thickness, the corresponding film stack layers may be formed via corresponding process operations, one corresponding process operation for each set of corresponding film stack layers. That is, unlike the prior 20 art, the film stacks of different thicknesses do not have to be formed via multiple sequential deposition and etching operations, one set of deposition and etching operations for one layer of one filter. In various embodiments, the same process operation or operations are ionized physical vapor deposition (IPVD) operation or operations.

25 While for ease of understanding, component **100** has been illustrated with only two FBAR filters **102a-102b** of different frequency bands, the invention is not

so limiting. As will be readily apparent from the descriptions to follow, the present invention may also be practiced to simultaneously form more than two FBAR filters of different frequency bands with film stacks of different corresponding thicknesses, where their corresponding layers are formed via 5 corresponding process operations (one corresponding process operation for each set of corresponding film stack layers).

Further, while for ease of understanding, the present invention is being described with embodiments where the corresponding layers of the film stacks of different FBAR filters are formed via corresponding same process operations, in 10 alternate embodiments, the present invention may also be practiced with non-corresponding like kind layers of the film stacks of different FBAR filters being formed via the same process operation(s).

For example, for the earlier described embodiment where each film stack 104a/104b includes a piezoelectric layer 112, sandwiched between two metal 15 layers 114a-114b, the bottom metal layer 114b of one film stack e.g. 104a may be formed with the top metal layer 114a of another film stack, e.g. 104b, via the same process operation.

Referring now to **Figure 2**, wherein a simplified cross section view of an 20 ionized physical vapor deposition (IPVD) apparatus suitable for use to make the FBAR filters of different frequency bands of **Fig. 1**, via the same process operation or operations, in accordance with one embodiment, is shown. As illustrated, IPVD apparatus 200 includes chamber 202 and complementary facilities 204 to bombard target 206 with an accelerated ionized gas to create 25 sputter materials 208, which may be Mo+ (as shown), for deposition on a substrate of a wafer 210 held on holder 212 within chamber 200. In various

embodiments, the target material is “neutral”. In alternate embodiments, the sputtered materials may be Al+ or other sputtered materials of like kind.

Further, for the embodiment, IPVD apparatus **200** also includes facilities **214** to allow an inductively coupled plasma (ICP) to be added to sputtered materials **208**. In alternate embodiments, IPVD apparatus **200** may be a sputter system plus Microwave Electron Cyclotron Resonance (ECR) Plasma, a sputter system plus Hollow Cathode Magnetron sputtering, or other enhanced sputter system of the like.

Finally, IPVD apparatus **200** includes voltage circuits **216** to allow different bias voltages to be applied to different desired regions of the substrate of wafer **210**. Resultantly, by controlling the different bias voltages applied to the different locations, film stack layers of different thicknesses may be effectuated at the desired locations via the same process operation or operations.

In various embodiments, the bias voltages are direct current (DC) voltages, while in other embodiments, the bias voltages may be radio frequency (RF) voltages.

Except for the employment of multiple voltage circuits **216** to apply different bias voltage to different regions of a substrate of a wafer at the same time, IPVD apparatus **200** may otherwise be any one of a number of IPVD apparatuses. Similarly, voltage circuits **216** may be implemented in any one of a number of manners.

Referring now to **Fig. 3**, where a method of the present invention for making different film stack layers of different FBAR filter in a same process operation, in accordance with one embodiment, is shown. As illustrated, for the

embodiment, process **300** starts with placing a wafer inside the earlier described chamber of **Fig. 2**, block **302**.

Next, gas is first ionized and accelerated, block **304**. Then, the ionized and accelerated gas is employed to bombard a neutral target, block **306**, to
5 create sputtered materials within the chamber.

Further, inductively coupled plasma are added to the sputtered materials, block **308**. Upon the addition, different bias voltages are applied to different desired locations of the substrate, block **310**.

The levels of the bias voltages correspond to the thickness of the film
10 stack layers desired at the desired locations. As a result, film stack layers of different desired thicknesses may be formed for different FBAR filters at different locations of the wafer, by the same process operation.

Process **300** may be repeated for other different film stack layers, resulting eventually in the desired FBAR filters of the different frequency bands.

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Figure 4 illustrates a system in accordance with one embodiment. As illustrated, for the embodiment, system **400** includes a communication interface **402** for receiving and sending RF signals. Communication interface **402** includes a number of components, in particular, a RF transceiver **406** having front end
20 **408**. More specifically, for the embodiment, front end **408** is component **100** endowed with FBAR filters for different frequency bands, having film stacks of corresponding different thicknesses, in which at least some of the film stack layers of the different FBAR filters are formed via the same process operation(s) as earlier described.

Further, system **400** includes digital signal processor **404** coupled to communication interface **402** for processing the signals received, and providing communication interface **402** with the signals to be transmitted.

Depending on the applications, system **400** may include other 5 components, including but are not limited to volatile and non-volatile memory, mass storage (such as hard disk, compact disk (CD), digital versatile disk (DVD) and so forth), and so forth.

In various embodiments, system **400** may be a personal digital assistant (PDA), a wireless mobile phone, a tablet computing device, a laptop computing 10 device, a desktop computing device, a set-top box, an entertainment control unit, a digital camera, a digital video recorder, a CD player, a DVD player, or other digital device of the like.

Thus, it can be seen from the above descriptions, a novel component 15 having FBAR filters for different frequency bands with film stacks of corresponding different thickness, where at least some the film stack layers of the different FBAR filters are formed via the same process operation(s), method for so making such a component, and a system having such a component have been described. While the present invention has been described in terms of the 20 foregoing embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims.

Thus, the description is to be regarded as illustrative instead of restrictive 25 on the present invention.